TAGA NextGen

Color Measurement Instrument Uncertainty: Examining Real-World Strategies for Informed Conversations Regarding Instrument Agreement

A Technology in Action Presentation

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TAGA NextGen

2026

Technology in Action

- Inspiration from Lucideon
  - Lucideon (formerly CERAM) is a Materials Science Consultancy Headquartered in Stoke-on-Trent, UK
  - For Color Measurement
    - CCSII (Colour Standards Series II) Tiles
      - Otherwise Known as BCRA Tiles or Lucideon Tiles

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New Product from Lucideon

- Printing Standards
  - 14 CCS-II Tiles Specifically Designed for Printing Companies to Inform Color Measurement Instrument Uncertainty

How Can CCS-II Tiles be Used?

- Inform Discussions of Instrument Uncertainty and Performance in a Real-World Setting

Definitions: Instrument Uncertainty

Precision

- The Closeness of Agreement Between Test Results Obtained Under Prescribed Conditions

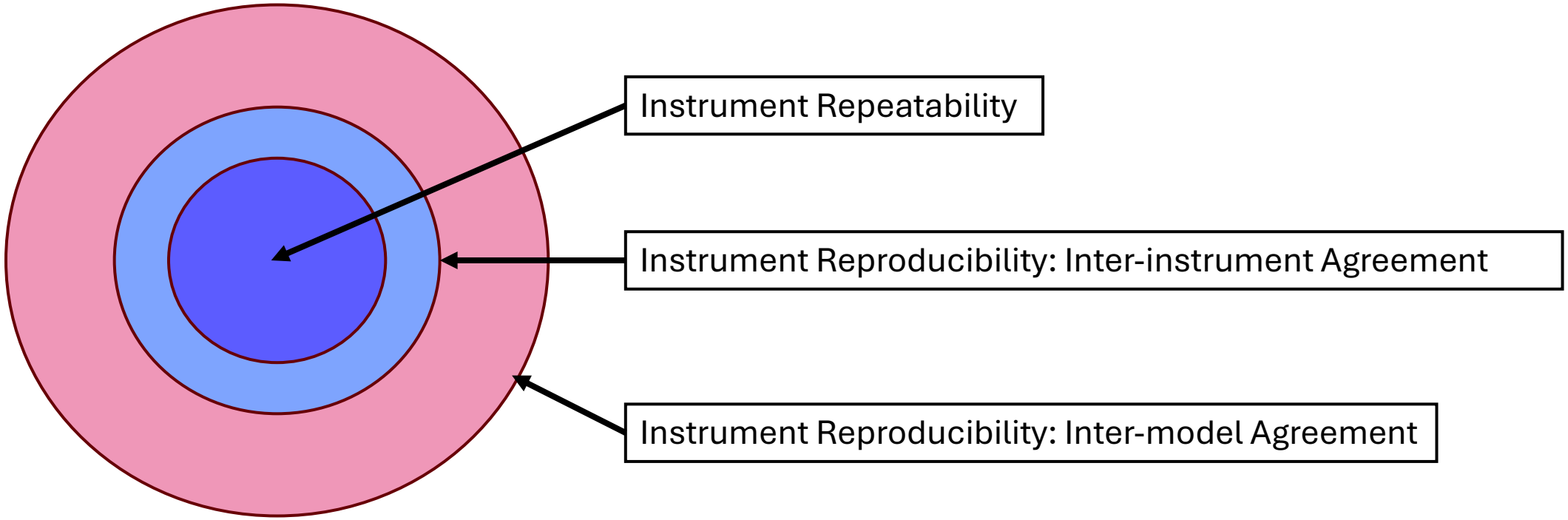
Accuracy

- The Closeness of Agreement Between a Test Result and an Accepted Reference Value (Berns, p. 125)

Definitions: Color Measurement Evaluations

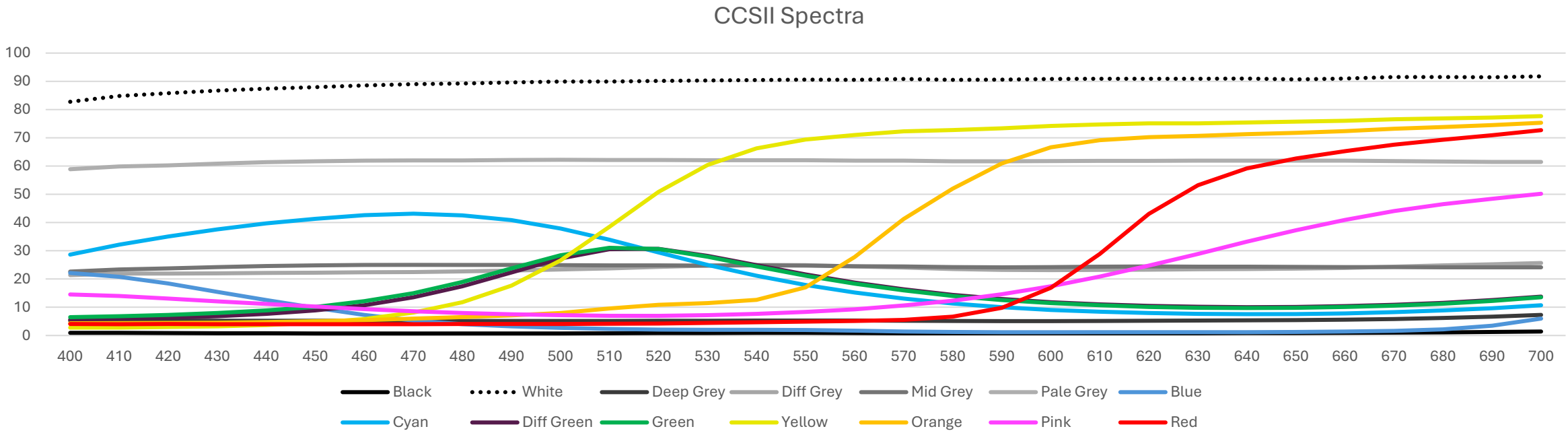
- Repeatability
  - How well and instrument can repeat identical measurements
  - “…the degree to which an instrument makes self-consistent measures”
- Reproducibility
  - “…the degree to which an instrument makes consistent measurements even when conditions are slightly changed
  - Can be different operators, models, or other variables
- Inter-instrument Agreement & Inter-model Agreement
  - Special Cases of Repeatability
    - **Inter-instrument Agreement**: Instruments of Identical Design
    - **Inter-model Agreement**: Instruments of the Same Type but Different Design

Likely Variance



What is the Specimen Measured?

- The Case for Lucideon CCS-II Tiles
  - Set of 12 Glazed Ceramic Tile Standards



CCS-II Tiles vs Other “Standards”

- Stability
  - Less Thermochromatic
- Uniformity
- Ability to Clean
- Instrument Manufacturer Agnostic

“Materials for working standards for regular use are chosen for their permanence and resistance to change with use and cleaning. The majority of working and instrument standards and every day use are of ceramic materials…

…“Ideal” specimens are smooth, uniform, flat, non-directional, and opaque in nature (Hunter & Harold, 1987, p. 309.)

What Do We Know About Published Color Measurement Instrument Uncertainty?

- Published Information; e.g., X-Rite eXact:
  - Average 0.25 ΔEab, Max 0.45 (for M3: 0.55 ΔEab)*
  - (Measurements using X-Rite manufacturing standards at a temperature of 23° C +/- 1° C, 40 – 60% RH for all measurement modes on 12 BCRA color tiles and a white ceramic reference (D50, 2°))
- Printed Samples May Not Fit “Max 0.45 ΔEab” Among New Instruments
  - e.g., Different Surface Characteristics, Uniformity

* “Signal to Noise” with Polarization Filter, Reminder to Be Careful with Aperture Size, as well

What Does This Mean?

- New Instruments Compared to a “Master Instrument” as a QC Check Before They are Shipped
  - We Know Little About the “Master Instrument”
    - A Challenge for Our Endeavor
  - It May be the Last Time That Instrument Measures That Set of CCS-II Tiles
- Other Instrument Manufacturers Provide Even Less Information

Handheld SpectroDensitometers

- Mid 1990s
  - Handheld Spectrodensitometers for Printing Industry Introduced, e.g.,
    - Gretag SPM 100
    - X-Rite 938
- “Production Grade” vs “Laboratory Grade”

Our Goals

- Our Goals
  - Usefulness Within Parameters
- Increase Confidence Regarding Instrument Uncertainty
  - Early Warning of Potential Instrument Problems
- Increase Agency
  - Manufacturers Seek “Renewable Revenue”

“Master Standard” Challenge

- Potential Adopters of CCS-II Tiles Likely Manage a Population of Instruments
  - Various Ages, Time Since Last Certification
  - “Legacy” (Discontinued) Instruments Continue to be Used
- Mean CIELAB Values of Population of Instruments for Each Tile as a Digital Master Standard?
- Creates a Moving Target in Many Applications
  - Data Collected With New Instrument (or, newly certified instrument) is Very Useful

Important to be Mindful…

- …Realistic Expectations of Variance
- …Application in Which Instrument is Used
  - Every Facility is Different

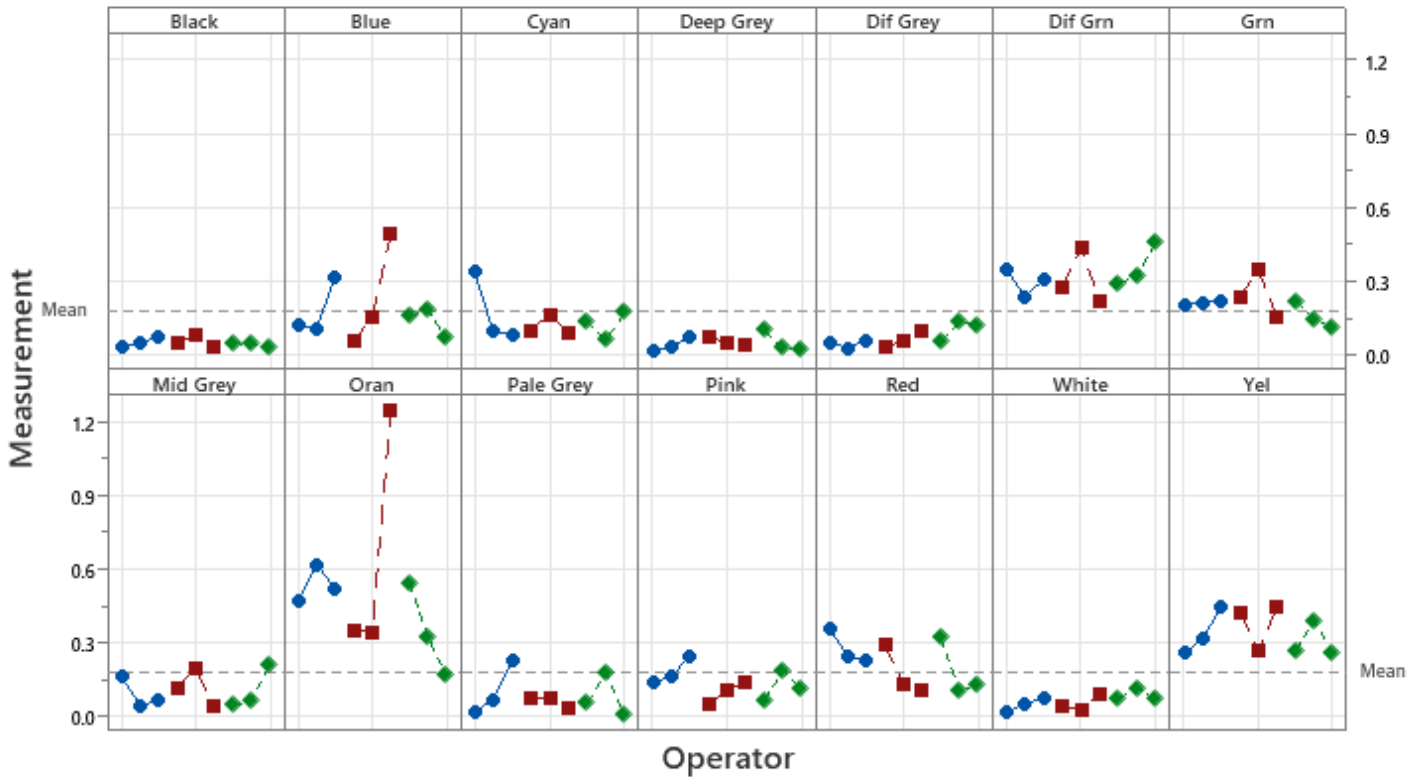
Look at Data

- Single Instrument
- Three Trained Operators
- Three Different Non-Sequential Readings of Each Tile
- Standard for ΔEab Based on Mean Values of All Readings for Each CCS-II Tile

Example: Blue Tile

Operator	Reading	L*	a*	b*	ΔEab
1	1	14.49	15.93	-36.81	0.06
1	2	14.34	16.09	-36.95	0.23
1	3	14.33	16.26	-37.19	0.49
2	1	14.93	15.78	-36.78	0.47
2	2	14.31	16.13	-36.96	0.28
2	3	14.37	16.15	-36.98	0.27
3	1	14.51	15.76	-36.53	0.39
3	2	14.55	15.93	-36.82	0.06
3	3	14.63	15.81	-36.65	0.28
“Master Instrument for Blue”		14.51	15.98	-36.85	

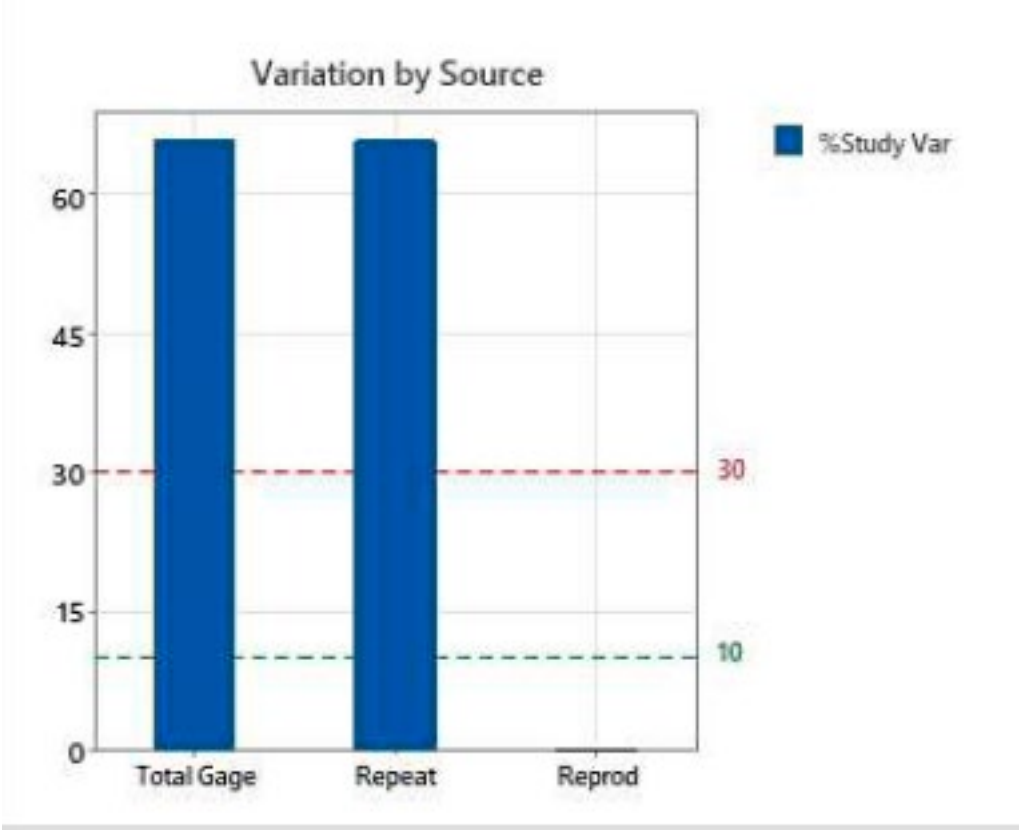
Gage Run Chart: Instrument 1



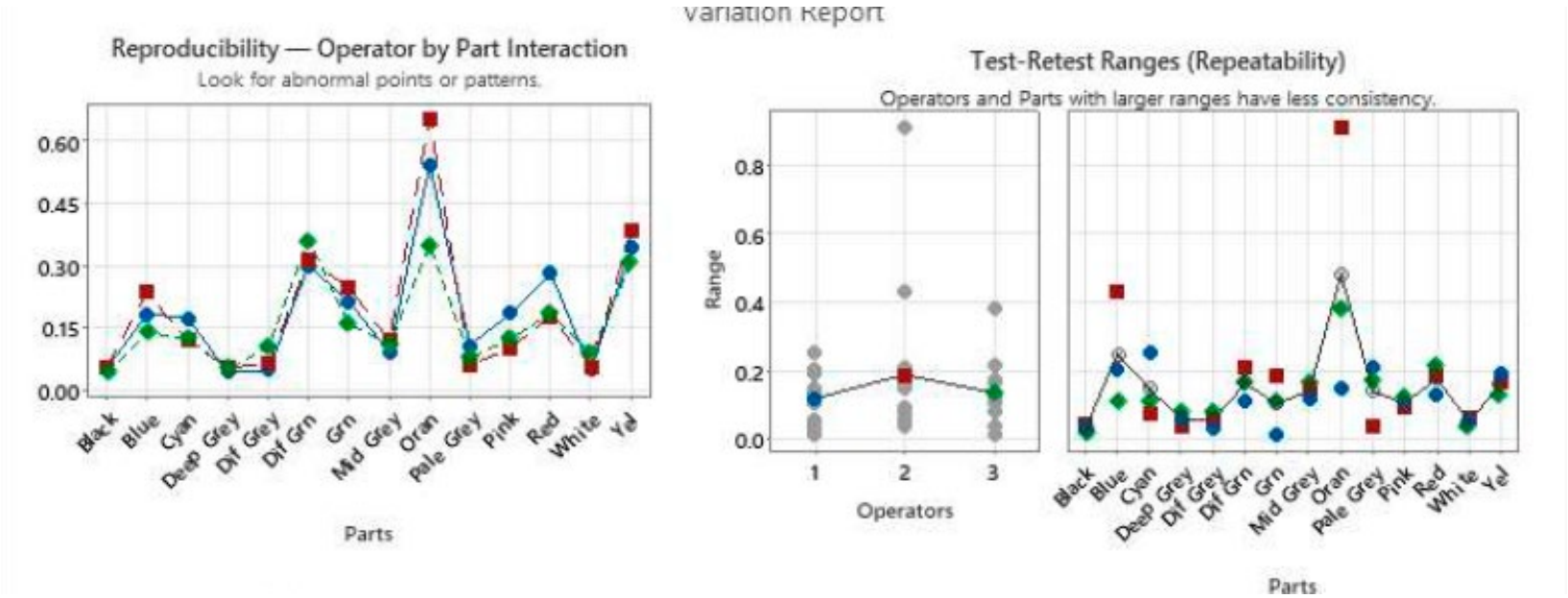
Gage R&R Instrument 1

- Reproducibility by Operator
- “Historical Standard Deviation”
- Here, Set at Standard Deviation for All Readings from Instrument 1 (0.166)

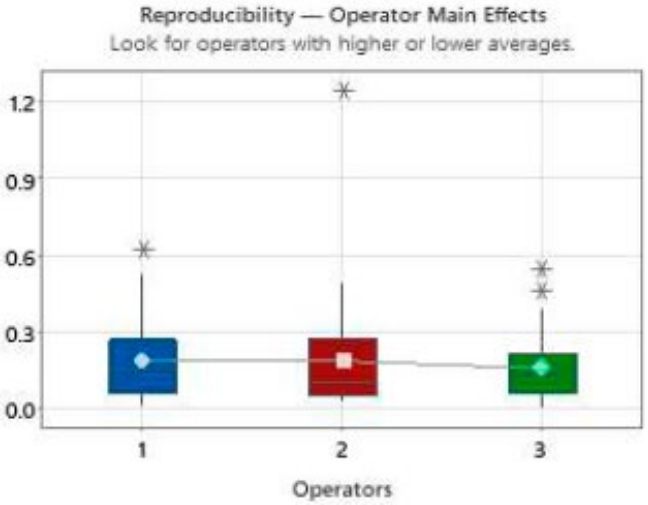
Gage R&R Instrument 1



Gage R&R Instrument 1



Gage R&R Instrument 1



Parts

Source	StDev	%Study Variation
Total Gage	0.109	65.61
Repeatability	0.109	65.61
Reproducibility	0.000	0.00
Operator	0.000	0.00
Part-to-Part	0.125	75.47
Study Variation	0.166	100.00

Study Variation (StDev): historical standard deviation

The Operator by Part interaction was not statistically significant and was removed from the table.

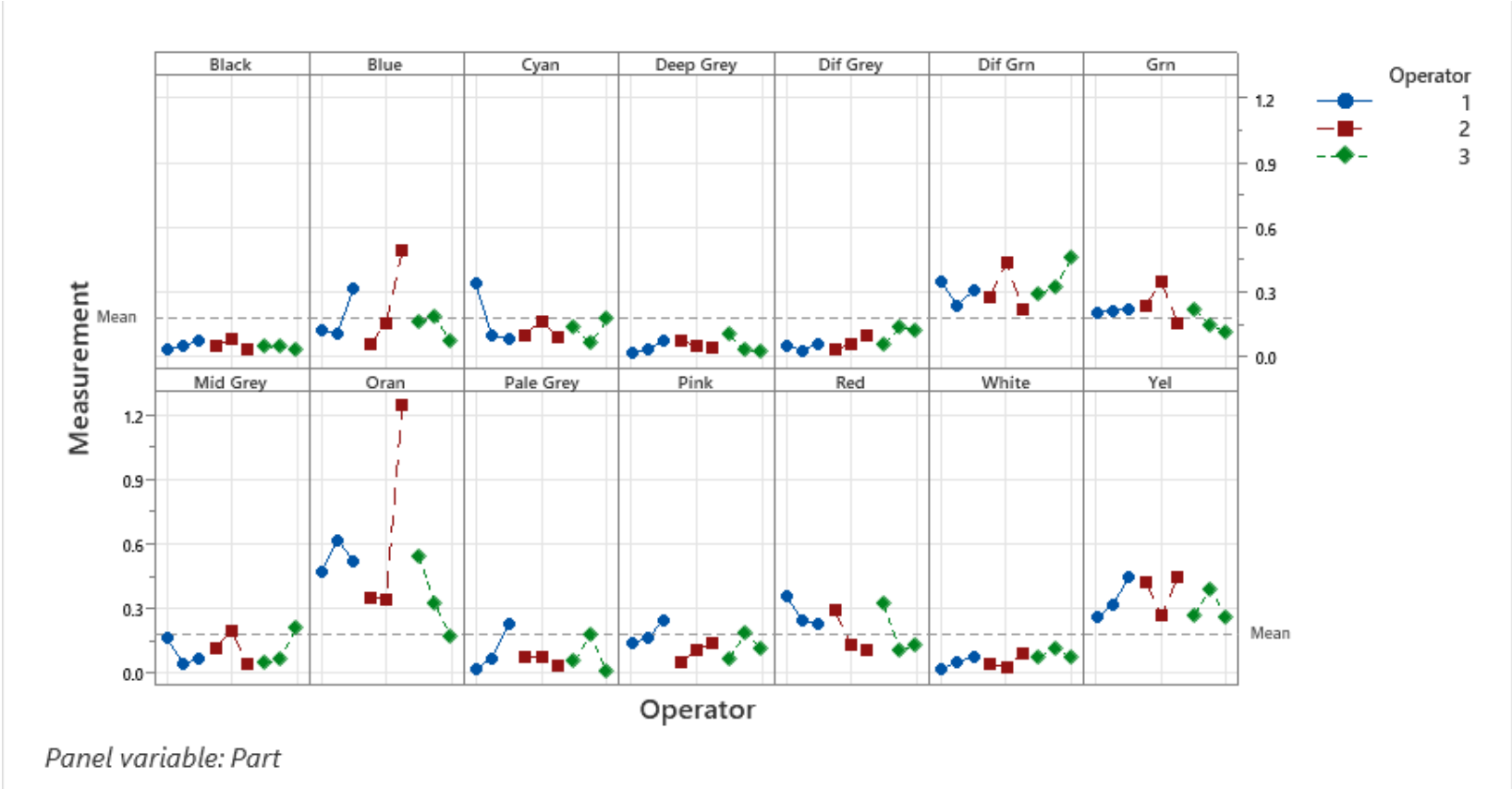
For Population of Instruments

- Three Instruments (Instrument 1 Plus Two Others)
  - Three Operators
  - Multiple Readings of Each Tile
  - Averaged into Single Data Point for Operator/Tile
- Reproducibility Now Based on Instrument Serial Number
- New “Master Instrument”
- Standard Deviation: 0.6423

Population Versus Single Instrument “Master Instrument”

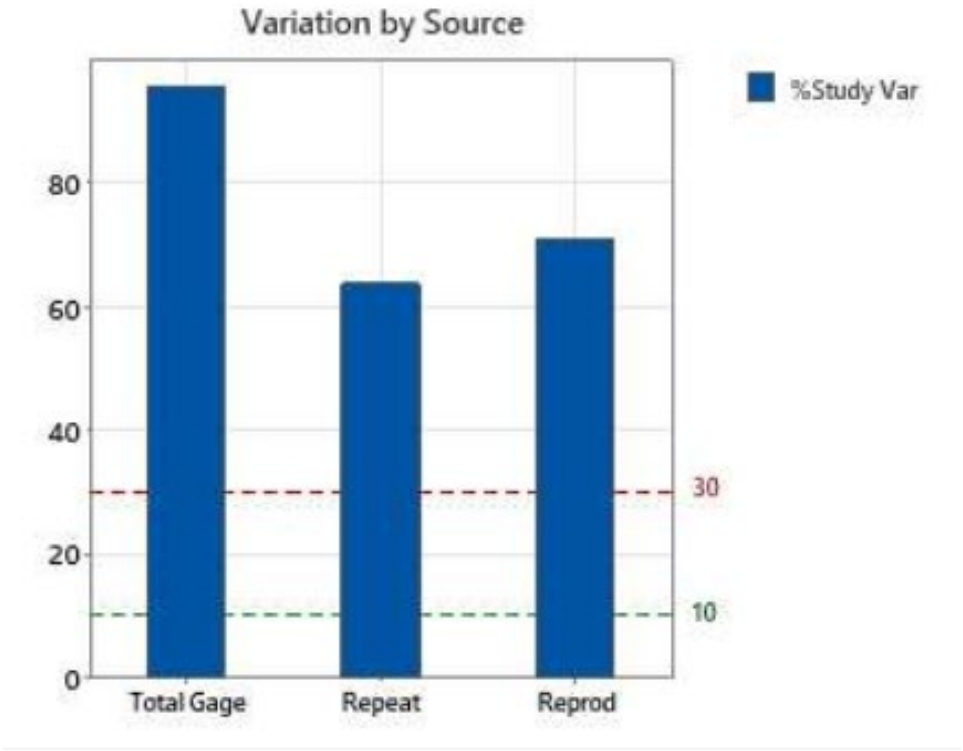
	3L*	3a*	3b*		1L*	1a*	1b*	ΔEab
Black	7.74	-0.89	1.48		7.80	-0.88	1.47	0.07
White	95.84	-0.21	1.54		96.22	-0.22	1.83	0.48
Deep Grey	27.49	0.05	-0.06		27.61	0.06	0.04	0.16
Dif Grey	56.23	-2.16	2.69		56.28	-2.15	2.85	0.17
Mid Grey	56.83	-0.65	-0.36		57.02	-0.65	-0.13	0.30
Pale Grey	82.71	-0.29	0.22		82.90	-0.28	0.46	0.31
Blue	14.64	16.04	-36.94		14.77	15.96	-36.93	0.15
Cyan	49.90	-17.66	-34.07		50.12	-17.81	-34.02	0.28
Dif Grn	50.01	-32.43	16.56		50.95	-32.73	16.87	1.03
Grn	50.93	-33.10	13.33		51.06	-33.08	13.45	0.17
Yellow	83.33	0.13	84.29		83.56	0.11	84.42	0.26
Orange	64.15	42.16	62.53		64.79	42.17	62.89	0.73
Pink	41.71	30.96	7.27		41.91	31.10	7.49	0.33
Red	40.97	52.38	29.57		41.19	52.57	29.76	0.34

Gage Run Chart Population of Three



* “Operator” is Instrument Serial Number in this Instance

Gage R&R Population of Three



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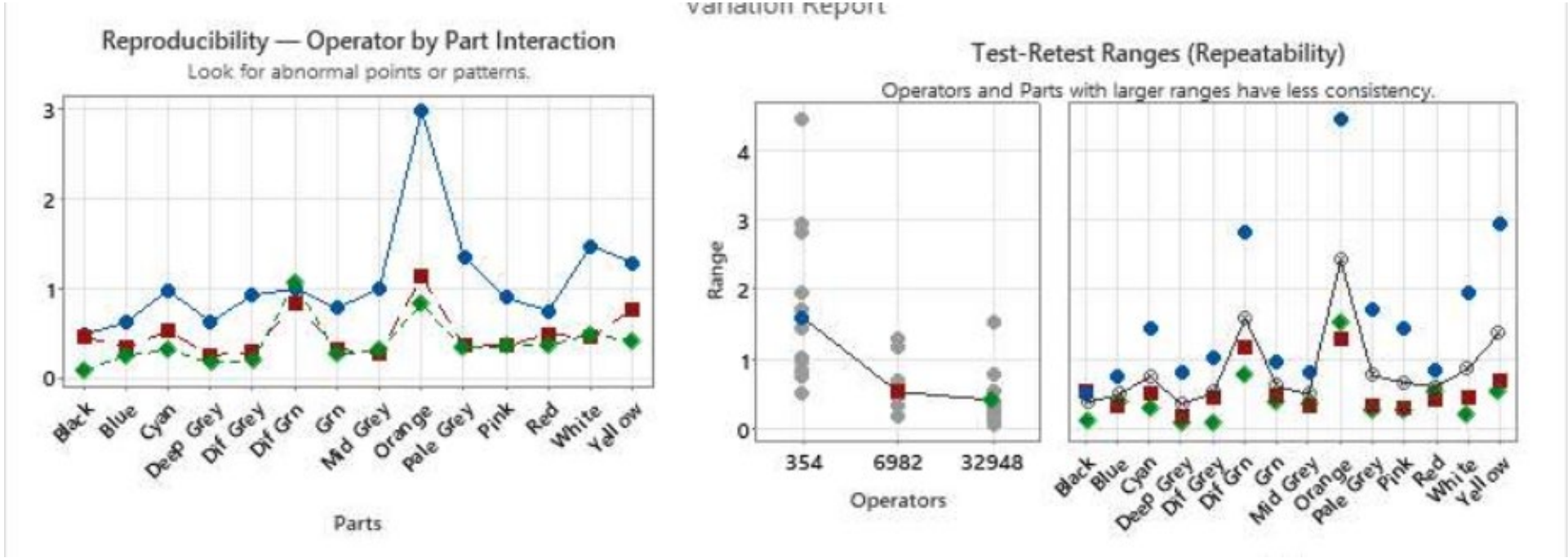
Gage R&R Population of Three



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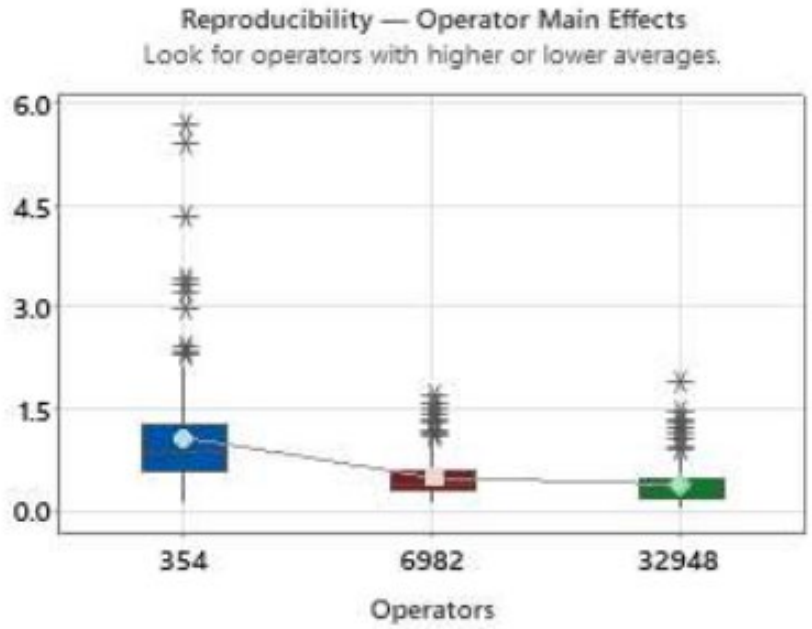
Gage R&R Population of Three



Parts

Source	StDev	%Study Variation
Total Gage	0.610	94.99
Repeatability	0.408	63.53
Reproducibility	0.454	70.62
Operator	0.370	57.58
Operator by Part	0.263	40.90
Part-to-Part	0.201	31.25
Study Variation	0.642	100.00

Study Variation (StDev): historical standard deviation

* “Operator” is Instrument Serial Number in this Instance

Remove Problem Instrument from Population

- Send for Recertification
- Need to Recalculate “Master Instrument” for All Instruments

Conclusions

- Challenges Include
  - Creating a “Master Instrument” Based on Population
    - Potentially, a Moving Target
  - Real Process Standard Deviation
- Nonetheless..
  - Data Obtained are Useful to Inform Process Control
    - Identify Potential Problems
    - Early Warning
    - Operator Training

Nod to Berns and Reniff (1997)

- “An Abridged Technique to Diagnose Spectrophotometric Errors” *Color Research and Application*, February 1997, pp. 51-60
  - “Measuring the cyan tile on a regular basis and transforming its colorimetric coordinates into spectrophotometric error metrics provides a useful method to validate the accuracy and reproducibility of a color measurement instrument.”
- Influenced Legacy Gretag-MacBeth Instruments
  - Tile included with new spectrophotometer
  - X-Rite included enamel blue, brown, and white with 938 & 939

Other Schema to Build Confidence, Various Levels of Cost and Agency

- X-Rite Net Profiler
  - Assure Instrument Performance to Master Instrument Between Instrument Recertifications
- Techkon SpectroCheck
  - Instrument Verification
  - 8 Ceramic Tiles traceable to NIST
  - Works with Handhelds and Pressroom Scanners